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(54) Touch sensitive device

(57) A touch sensitive device is provided having a laminar light guide 10, inside which light from source, such as the screen of a CRT 20 can become trapped by total internal reflection after reflection from a finger. The edges of the guide 10 are fitted with photodetectors 101 which respond to the entrapment of light between the surfaces. It is possible, by comparing the photodetector output with the CRT raster position, to determine the exact surface position of the touch. Alternatively a flexible transparent membrane over the light guide may be pressed in contact therewith by the finger. Other wave energy may replace light.

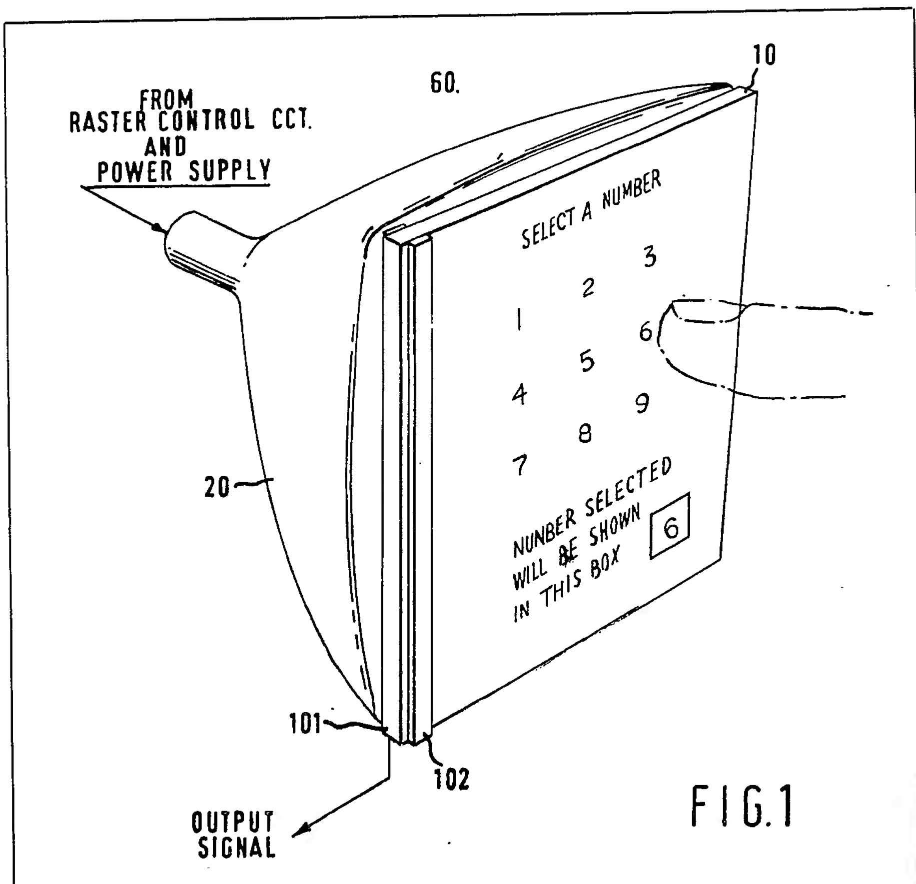


FIG.1

FIG.1

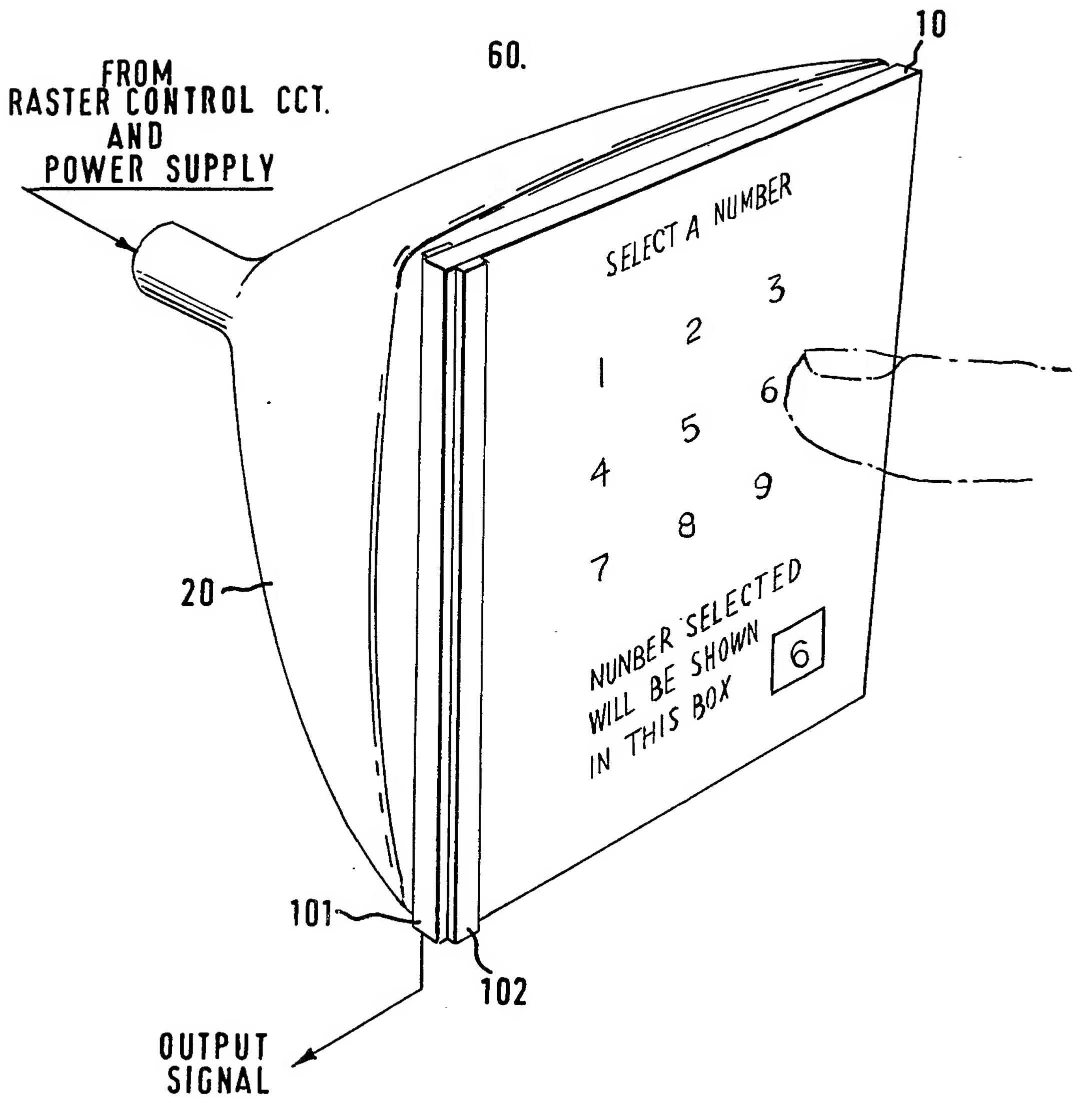

FROM
RASTER CONTROL CCT.
AND
POWER SUPPLY
60.
10
SELECT A NUMBER
1
2
3
4
5
6
7
8
9
NUNBER SELECTED
WILL BE SHOWN
IN THIS BOX
6
20
101
102
OUTPUT
SIGNAL

FIG.2

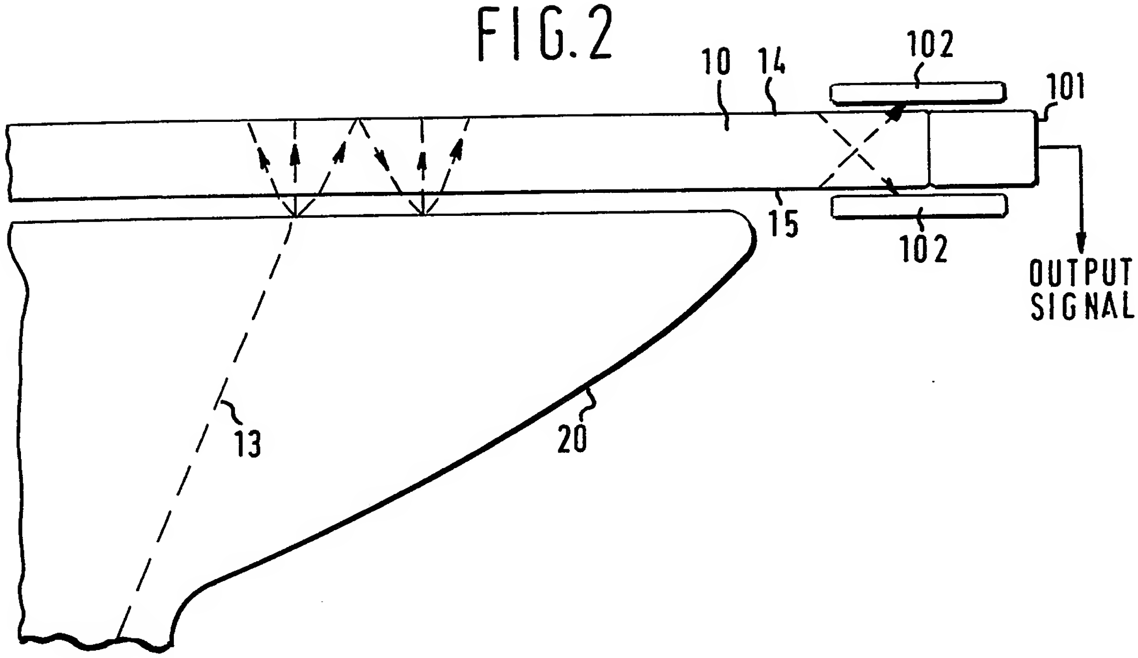

10
14
102
101
15
102
OUTPUT SIGNAL
13
20

FIG.3

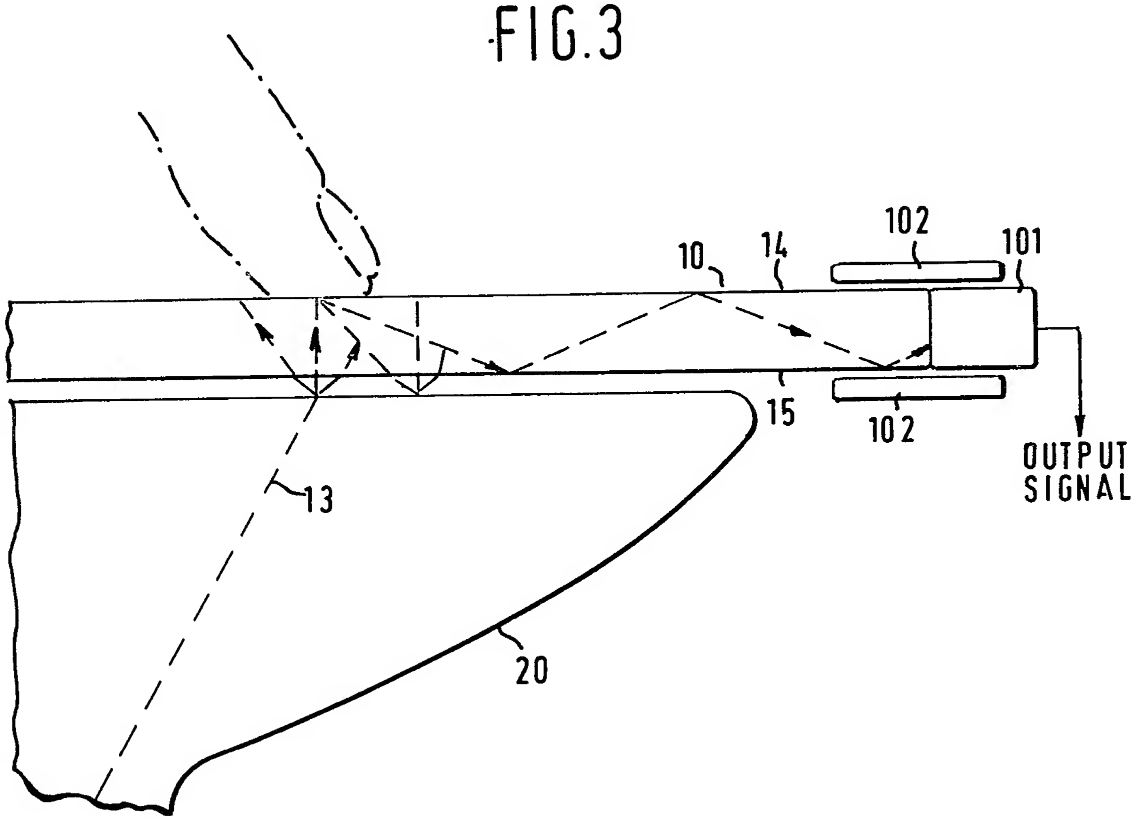

10
14
102
101
15
102
OUTPUT SIGNAL
13
20

FIG.4

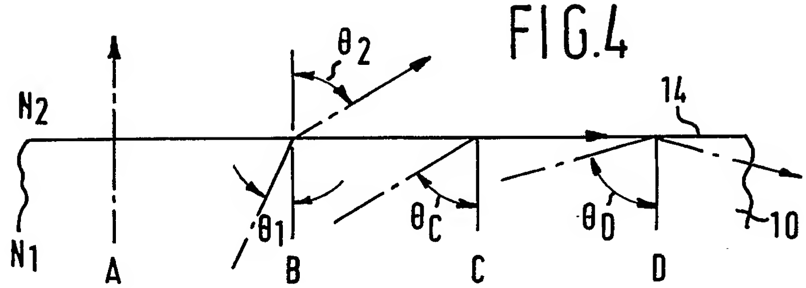


FIG.5

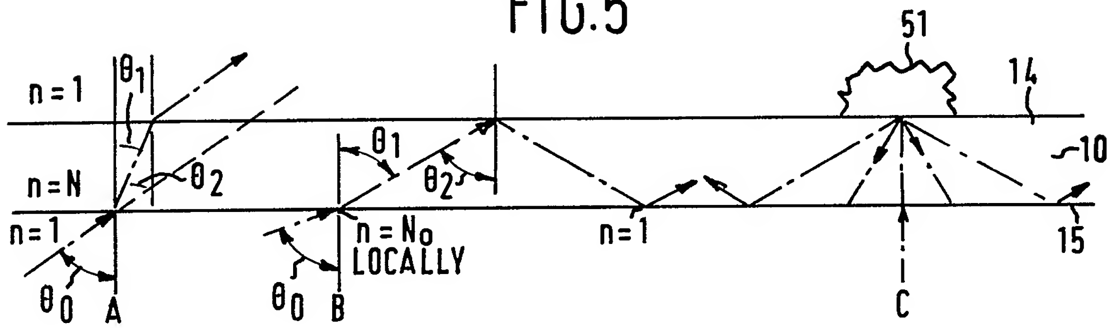


FIG.6

60.

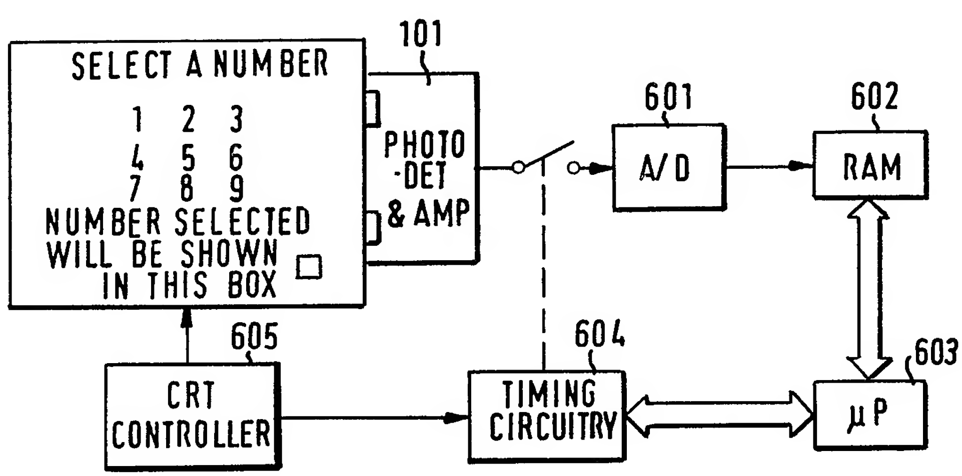


FIG. 7

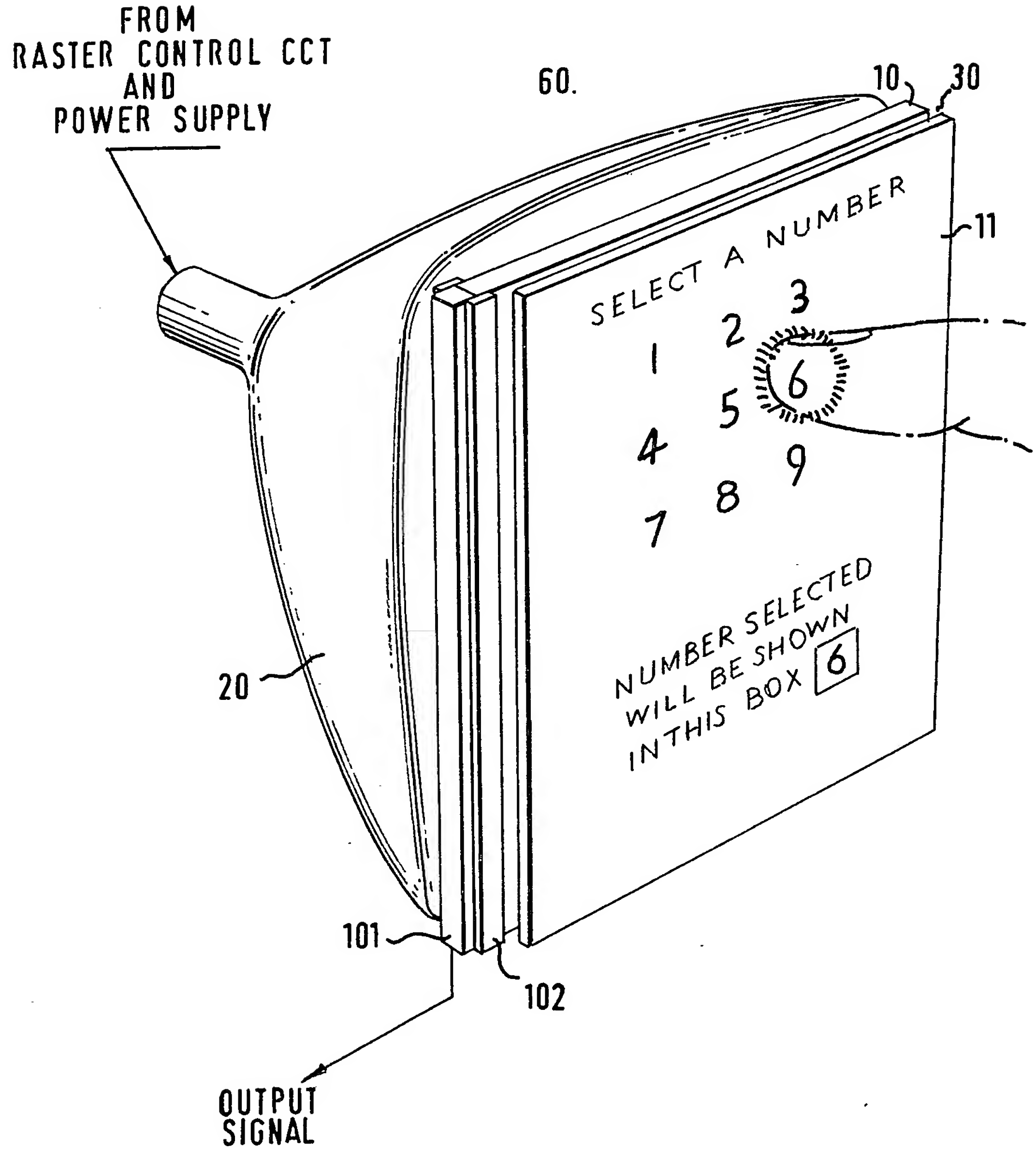

FROM
RASTER CONTROL CCT
AND
POWER SUPPLY
60.
10
30
SELECT A NUMBER
11
1
2
3
4
5
6
7
8
9
NUMBER SELECTED
WILL BE SHOWN
IN THIS BOX
6
20
101
102
OUTPUT
SIGNAL

FIG.8

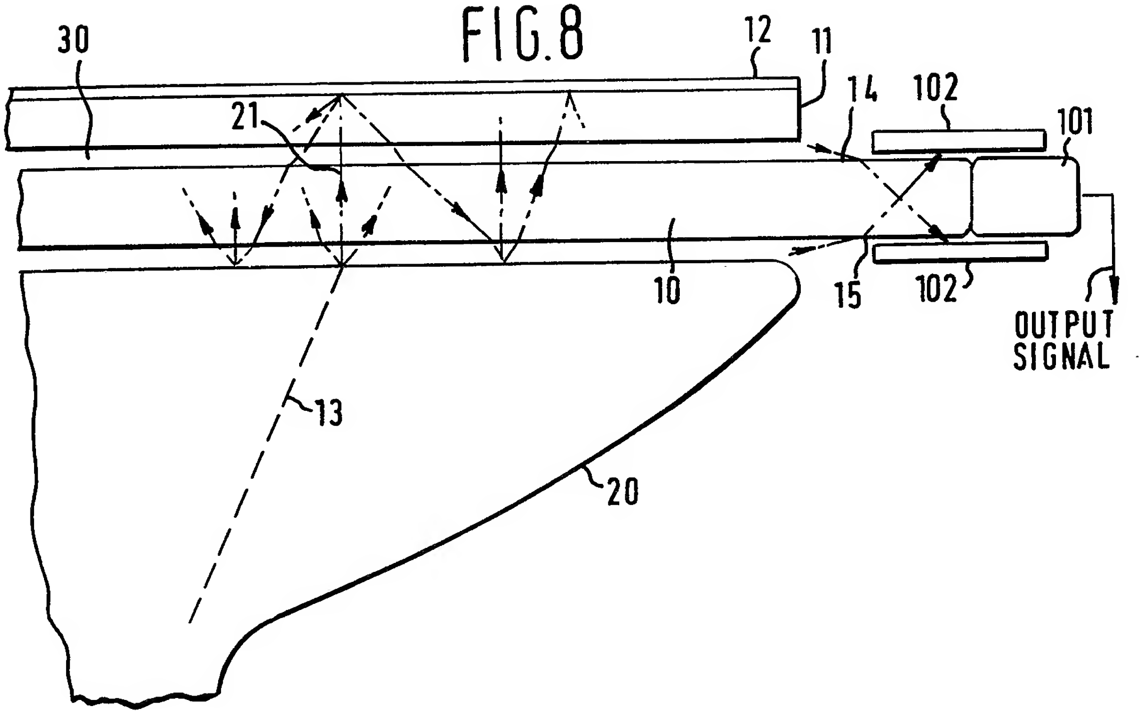
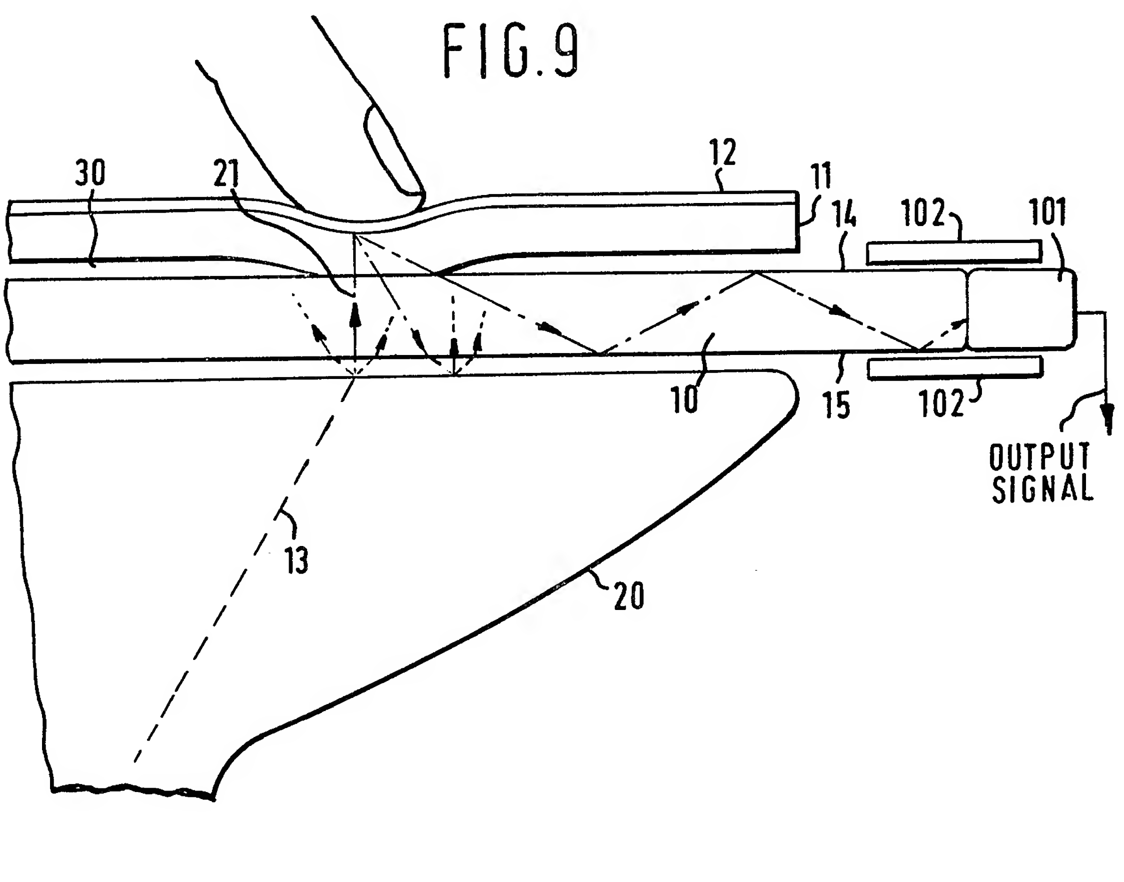

30
12
11
21
14
102
101
10
15
102
OUTPUT SIGNAL
13
20

FIG.9


30
21
12
11
14
102
101
10
15
102
OUTPUT SIGNAL
13
20

SPECIFICATION

Touch sensitive device

This invention relates to touch sensitive devices and more particularly to a touch sensitive device for use with a synchronized light source, such as a cathode ray tube (CRT) for determining the position of a surface contact.

There are many applications where it is desired to provide feedback information for information displayed on a CRT screen. For example, it has become common practice with the use of computers to display on the screen a choice for the user to select from. The user is typically instructed to operate specific keys, on a keyboard or similar device, to select from among a menu of possible choices. In response to the user operating the selected key the menu is changed and the user is given a new choice, again making the choice by operating a particular key. Such an arrangement is tedious since a user must first look at the screen and then go to a separate keyboard to find the proper key. This is time consuming and requires costly separate equipment.

One possible solution to the problem has been to arrange the menu of choices along a side of the viewing screen and to arrange next to the screen a series of buttons. As the labels on the screen change the buttons become dynamically relabeled. While this solves some of the problems it does not allow the complete flexibility of the visual display and still requires an artificial arrangement of the display.

Several attempts have been made to solve the problem, one such being the use of a light pen which is held over the point on the CRT screen corresponding to the desired response. Light from the CRT raster then enters the pen and the position of the raster is determined by comparing the signal output from the pen to the position of the raster beam at the time of the signal. This arrangement, while performing properly, has the disadvantage of requiring the user to hold a pen and to properly direct the pen to the proper place on the screen.

Other touch sensitive screens use cross wires, crossed beams of infra red light, reflection of acoustic surface waves, current division in resisitive sheets, force balancing, or mechanical buttons on which a display image was superimposed by a half silvered mirror. When used with a CRT display, the foregoing methods require careful calibration to establish correspondence between points on the touch screen and points on the display. The need for special transducers or many electrical connections increase complexity and cost.

Thus, it is desired to solve these problems in a manner which allows the visual display to be touched directly at any location on a dynamically changing basis with the position of the touch being easily determinable.

According to the present invention there is provided a touch sensitive device for use in conjunction with a signal source, said device comprising means having spaced apart surfaces arranged such that signals are introduced between said surfaces so as to become entrapped within said means by total internal reflection between said surfaces as a result of a change in medium bounding at least one of said surfaces, said medium change occurring as a result of said device being touched so as to provide an output indicative thereof.

In one device in accordance with the present invention, it may be arranged that said medium change occurs as a result of the said one surface being touched.

In another device in accordance with the present invention a flexible overlay may be provided adjacent to said one surface, said overlay being adapted to be deflected into contact with said one surface to effect the said medium change in response to said overlay being touched.

In yet another device in accordance with the present invention, it may be arranged that the means having the spaced apart surfaces is flexible, and is deflected in response to a touch thereof to cause said medium change to occur.

Some exemplary embodiments of the invention will now be described, reference being made to the accompanying drawings, in which:

Figure 1 is a pictorial view of a CRT screen overlaid by a touch sensitive device according to the present invention;

Figures 2 and *3* are schematic representations showing a top view of the arrangement of Fig. 1, the device being in the untouched and touched conditions, respectively;

Figures 4 and *5* depict the principle of operation of the touch sensitive device according to the present invention;

Figure 6 is a block diagram of an operational system for deriving a touch position signal from the touch sensitive device of Fig. 1;

Figure 7 is a pictorial view of a CRT screen overlaid by a modified form of the touch sensitive device depicted in Fig. 1, and

Figures 8 and *9* are schematic representations showing a top view of the arrangement of Fig. 7, with the touch sensitive device in the untouched and touched conditions, respectively.

In Fig. 1, CRT 20 is operated in the well known manner such that electrons from the electron gun (not shown) impinge upon the phosphorescent screen of the CRT in a sequential pattern, line by line, from top to bottom. As the electrons hit the phosphorescent surface the surface glows. Phosphorescent images can be formed on the screen under control of the electron beam.

By properly programming the system it is

possible to have any type of image dislayed at any position on the screen for any length of time. Thus, it is possible to create images representative of numbers, sets of numbers, letters, or signals in any position on the screen. Using a touch sensitive device in accordance with the present invention, it is possible to allow a user to touch any position on the screen and to determine electronically the position of the touch. In order to accomplish this, the CRT screen is overlaid with device 10 having parallel surfaces through which light from the phosphorescent screen may pass.

When the CRT screen projects an image calling for user response, a finger or other device is placed against screen 10 at the position selected (the number 6 in Fig. 1). When this occurs, as will be explained from that which will follow, light becomes trapped within device 10. This trapped light travels to the edge of the device and is detected by photodiodes 101 thereby providing an output signal useable for determining the position of the touch. The actual determination of the touch position is accomplished by comparing the position of the CRT raster to the time of the output signal as will be briefly described with reference to Fig. 6 of the accompanying drawings. This comparison and determination is the subject of U.S. Patent Application Serial No. 140,714.

Turning to Fig. 2, CRT raster beam 13 is shown impinging on the front surface of CRT 20 with light rays 21 from the phosphorescent surface passing through the parallel surfaces 14 and 15 of device 10 and out into air. Most of the light rays are transmitted outward toward the user while some are reflected back toward the CRT screen. Because of the air gap between lower surface 15 and the front of the CRT 20 the reflected light rays (as will be discussed) have an angle of refraction greater than the critical angle needed for total internal reflection and thus do not become trapped within device 10. These light rays, as they approach the edge of device 10, can never assume an angle sufficient to become trapped between surfaces 14 and 15 and thus as light approaches the edge of the device, it passes into a light absorbing surface such as surface 102 which may be black plastic. Very little additional light impinges upon photodiode 101 and thus the output signal from the photodiodes 101 reflects internally scattered light and has a value which, while constantly changing, is known for any instant in time.

In Fig. 3, a finger is shown applying pressure at a point on top surface 14 of device 10. Reflectivity of the finger, as well as a change in the medium at the point of contact cause light to be reflected back into device 10. These reflected light rays do not refract as they did in Fig. 2 due to a refraction angle change (as will be discussed) and thus become trapped between surfaces 14 and 15 of device 10 by total internal reflection.

This trapped light then travels, as shown, within device 10 and impinges upon the photodiodes 101. Note that light absorbers 102 are ineffective to absorb this light since the light rays do not pass through surfaces 14 and 15. Thus, the light rays which impinge upon photodiodes 101 cause an output signal which is different from the output signal generated when light does not impinge upon the photodiode.

It is important to note that the photodiodes 101 may be replaced by any type of device for converting optical or other signals to electrical energy and may be a single device or may comprise a number of individual devices. In some applications a device at one surface would be sufficient while in other applications it would be advantageous to surround device 10 on all sides with such a transducer which, of course, may have a single output or multiple outputs. In some applications, the transducer may communicate with the edge of device 10 through a suitable light conduit, and thus may be physically located at any convenient location.

In order to even out the detector response the edges of the device, between the parallel surfaces can be coated white, or they may be polished and silvered.

Also, it has been found that by using two-color sensitive detectors (such as red sensitive and blue sensitive) undesirable scattering effects can be reduced. To do this the outputs of two photodetectors having different spectral sensitivities may be mixed in such a way that the signals produced by light scattered from colorless objects (e.g., most greases and the surface imperfections of device 10) are nulled out. When this has been done most colored objects (e.g., the human finger) will still produce a substantial output signal.

In some instances it may be desirable to interpose miniature louvers or other directionally transparent material between the display screen 20 and device 10 in order to improve spatial resolution. This will especially be useful when the material bounding device 10 on the display side does not have an extremely low refractive index.

Though in this embodiment arrows have been shown on light rays to indicate a particular direction of propagation, light paths are always reversible, and thus a dual of the device described here can be constructed by replacing the photodetector with a photoemitter, and replacing the scanned display screen with a scanned photodetector array.

If this device is used with a cathode ray tube very careful electrical shielding will be essential. In particular, interposing a ground plane between the CRT and the photodetectors is very helpful. Also, CRTs having phos-

phors with very fast initial decays will work best.

Total Internal Reflection Criteria

Refraction at a single surface between media of refraction index N_1 anf N_2 is shown in Fig. 4. Light ray A is perpendicular to the boundary and does not undergo refraction. Light ray B enters the boundary with an angle $\theta 1$ and is refracted according to Snell's law which states

$$N_1 \sin\theta_1 = N_2 \sin\theta_2 \qquad (1)$$

Light ray C approaches the boundary with angle θ_C which is the critical angle for total internal reflection. This critical angle, when $N_2 = 1$, which is the case for air, is shown by the formula

$$\sin\theta_C = N_2/N_1 = 1/N_1 \text{ when } N_2 = 1 \text{ (air)} \qquad (2)$$

Total internal reflection takes place when θ is larger than the critical angle such that θ_D is greater than θ_C. Since sin of θ is less than 1 it follows that N_2 must be less than N_1 for total internal reflection to take place.

Turning now to Fig. 5, the conditions for total internal reflection (TIF) will be reviewed with respect to a device of refractive index N with air (refractive index = 1) at the surfaces of the device. When light ray A enters device 10 from air, total internal refraction cannot take place because the index of refraction at the lower surface bends the light ray to an angle smaller than the critical angle necessary for total internal

refraction which is $\frac{1}{N}$. This follows

from use of geometry and Snell's law since.

$$\sin\theta_1 = \sin\theta_2 = \sin\theta_o/N, \qquad (3)$$

and sin θ is less than 1 for all angles of θ less than 90°.

In the case of light ray B (Fig. 5) the air space is eliminated when the light ray is assumed to enter from a medium with an index of refraction $N_o > 1$ which occurs when another body is in contact with the bottom surface of device 10. Total internal reflection can now take place (where air borders the device) because the light ray is no longer bent to an angle smaller than the critical angle at the lower surface. This follows from the fact that

$$\sin\theta_1 = \sin\theta_2 = (N_o/N)\sin\theta_o \qquad (4)$$

which is greater than the critical angle $\frac{1}{N}$ when

$$N_o \sin\theta_o > 1. \qquad (5)$$

Likewise, a diffusely reflecting body 51 ($N > 1$) in contact with the top surface 14 of device 10 can scatter a light ray, shown as ray C in Fig. 5, in such directions that it becomes trapped by total internal reflections.

The afore-described device for determining a touch of a CRT screen involves the detection of light generated at the position on the CRT touched by the user, and arrangements similar to those used with light pens can be used to determine the position touched. Problems exist however, in that imperfections in the surface of the CRT screen, dirt, grease build-up, and geometrical aberrations all combine to cause some total internal reflection to occur at all times, even when no touch has occurred. The result is that the photodetectors produce appreciable output at all instants during which the raster beam is drawing bright areas on the CRT screen.

These problems are compounded in that for each cycle of the raster, the output wave form has a non-constant value resulting in a signal which, for a given point, may be greater in magnitude without a touch than is a portion of the signal output in the presence of a touch. Thus, it is not always practical to simply measure the signal level of the photodiode output in order to detect a touch signal. One means of solving these problems is to use an arrangement, which may conveniently be referred to as a sample spot system, which is founded, in part, on the understanding that a meaningful touch can only occur at one of a set of specified touch locations according to the pattern formed on the face of the CRT screen. A block diagram of an operational system which makes use of this sample spot system is shown in Fig. 6 of the drawings but will not be described in detail herein. The system is more fully described in the aforementioned U.S. Patent Application Serial No. 140,714. In the sample spot system the CRT screen is divided into nonpermanent locations designated touch areas and non-touch areas. The areas are changeable, as required, and may consist, at any point in time, as a single touch spot, or there may be several touch spots or areas spaced around the screen. The coordinate positions of the touch areas are stored in a memory and only signals generated while the raster beam is within the defined touch areas are considered by the sample spot system.

The sample spot system, during the times when the raster beam is within a defined touch area, samples the output from the pho-

todiodes on a time defined basis. The values of the signal at each defined time position are stored in a memory. The sampling and storing is timed to the CRT raster beam so that drifts in the video image will cause no problems.

The sample spot system operates to sample the photodiode signal during all times that the raster beam passes through CRT locations which are within the defined touch regions. This sample is made for several successive raster cycles and the averaged result for each raster position is stored in a separate memory location. This occurs at a speed fast enough that all the samples are complete before the first touch could possible occur. Thereafter, every time a frame is drawn on the CRT face by the raster beam, the photodiode output corresponding to each touch area is sampled and the sample for each time is compared to the priorly stored untouched average sample for that time. When one of the compared samples exhibits an increase (mismatch) in magnitude over the priorly stored sample, a touch signal is generated. Since the location of the mismatch in memory corresponds to a known position on the CRT screen the position of the touch on the screen is known exactly.

In Figs. 7 to 9 of the accompanying drawings there is depicted a modification of the touch sensitive device depicted in Fig. 1, in which a flexible membrane 11, which advantageously may be transparent silicane rubber, is provided overlaying and spaced from the top surface 14 of the device 10.

Membrane 11 may be separated from top surface 14 of device 10 by any one of several means such as, for example, stretching between supports or resting against ridges, protrusions, or flexible tabs dispersed about the surface. The flexible membrane 11 is advantageously constructed with a half tone white dot pattern on its outer surface (other patterns such as strips could also be used). This construction allows light from the CRT screen to pass through the membrane 11 to be viewed by a user as well as being reflected back towards the CRT screen. When the CRT screen projects an image calling for user response, a finger or other device is placed against the outer surface of the membrane 11 at the position selected (the number 6 in Fig. 7). When this occurs, as will be explained from that which will follow, light becomes trapped within device 10. This trapped light travels to the edge of the device and is detected by photodiodes 101 as already described with reference to Fig. 1.

Turning to Fig. 8, CRT raster beam 13 is shown impinging on the front surface of CRT 20 with light rays 21 from the phosphorescent surface passing through the parallel surfaces of device 10 and into membrane 11. Some light rays (not shown) are transmitted outward toward the user and some are reflected back toward the CRT screen. Because of the air gap 30 between the lower surface of flexible membrane 11 and outer surface 14 of device 10 the reflected light rays have an angle of refraction less than the critical angle needed for total internal reflection and thus pass through device 10. These light rays, as they approach the edge of device 10, can never assume an angle sufficient to become trapped between surfaces 14 and 15 and thus whatever light approaches the edge of the device, passes into the light absorbing surface 102, as described with reference to Fig. 1.

In Fig. 9, a finger is shown applying pressure at a point on the top surface of membrane 11 thereby flexing the membrane 11 into contact with surface 14 of device 10. Air is thus removed between membrane 11 and top surface 14 of device 10 at a point directly under the point of pressure contact. Membrane 11 has coated thereon a surface 12 which is made up, in one embodiment, of half-tone white dots to have increased reflectance and to scatter the light rays.

With the membrane depressed light generated on the surface of CRT 20 near the depression passes through device 10 and into membrane 11 and is then reflected back into device 10. These reflected light rays, since they do not now pass through air, do not refract as they did in Fig. 8 and thus some of these rays become trapped between surfaces 14 and 15 of device 10 by total internal reflection.

This trapped light then travels, as shown, within device 10 and impinges upon the photodiodes 101. Note that the light absorbers 102 are ineffective to absorb this light since the light rays do not pass through surfaces 14 and 15. Thus, the light rays which impinge upon the photodiodes 101 cause an output signal which is different from the output signal generated when light does not impinge upon the photodiodes.

To make the device more useful, the sides of the white dots facing away from the CRT should be made matte black. This increases the contrast of the CRT image as viewed by the user, which would otherwise be degraded by reflection of ambient light from the dots. The darkening may be done by a variety of means: for example oxidizing the exposed surfaces, or by photoetching the dots from a combined layer of white and dark material. Such contrast enhancement by overlaying matte black dots, would be useful for any CRT, even without the touch screen described here.

While the focus of the present disclosure is on a CRT type light signal the present invention may also find use in situations where it is desired to position a part in a particular location. In such an arrangement a fixed light source may be used at the desired location

and the part moved mechanically or otherwise to make contact with the flexible membrane. When the contact is at the location where the light is focused total internal reflection will occur. This total internal reflection will become visible to a person observing the device. Thus the device may be useful for determining a surface condition of a screen or other device. The device can also be constructed using the flexible membrane alone, with photodiodes coupled to its edge. If this membrane is positioned near the CRT face, but separated by an air gap, light from the CRT will pass through the sheet without reaching the diodes. However, if the membrane is flexed into contact with the CRT face at a point, some light rays from the CRT will become entrapped, impinge upon the photodiode, and cause an output signal which can be used as before for determining position. To improve this device, a second membrane having a smaller refractive index and partially light absorbent can be overlaid on the first membrane. Light will still be entrapped in the first membrane but the effect of oil and other contamination on the outer surface of the device will be reduced.

Although described as being applicable to light signals, it should be understood that the principles of the touch sensitive device described may be used in conjunction with other signals, such as acoustical or electronic so long as they obey the physical phenomenon described. It, of course, is to be understood that those skilled in the art may find many applications and modifications using the present invention and it may be built as a separate device for mating with an existing CRT or it may be manufactured as a part of the implosion screen itself. Also, the trapped light may be removed from the device by any light utilization device, such as, for example, fiber optics or light pipes.

Using the touch sensitive device described in graphics and taking advantage of the fact that multiple positions can be detected, a user could rotate a shape by touching two points and rotating them around each other. A user could position a line by simultaneously positioning its end-points; or could specify a quadratic curve by indicating three points along its length. Areas could be colored or shaded by touching them while pads indicating these attributes were simultaneously touched.

In text processing, a screen with relabelable keys could provide a shift button that could be pressed simultaneously with other keys. A text editor could combine cursor control and touch sensitive buttons on the same screen; and the buttons could be touched while the cursor was moved (to change the text font for example).

In the case of the Fig. 7 device, this can also be made to discriminate different levels of force. In graphics, this force discrimination could indicate a degree of shading, or could be translated into linear or rotational velocity.

Force discrimination could also be used to eliminate the effect of parallax; as cursor position could be indicated on the screen as the user moved his or her finger across the display, and the user could simply press harder when the desired position was obtained.

It would also be advantageous to make the flexible overlay of the Fig. 7 device translucent, and to focus an image upon it by means of projection television from the rear. This would give a large area screen and the focusing would lead to the finest spatial resolution.

CLAIMS

1. A touch sensitive device for use in conjunction with a signal source, said device comprising means having spaced apart surfaces arranged such that signals are introduced between said surfaces so as to become entrapped within said means by total internal reflection between said surfaces as a result of a change in medium bounding at least one of said surfaces, said medium change occurring as a result of said device being touched so as to provide an output indicative thereof.

2. A device as claimed in claim 1, wherein said medium change occurs as a result of the said one surface being touched.

3. A device as claimed in claim 1, comprising a flexible overlay adjacent to said one surface, said overlay being adapted to be deflected into contact with said one surface to effect the said medium change in response to said overlay being touched.

4. A device as claimed in claim 1, wherein the means having the spaced apart surfaces is flexible, and is deflected in response to a touch thereof to cause said medium change to occur.

5. A device as claimed in any preceding claim, comprising signal utilization means communicating with a region between said surfaces for affording said output when said signals are introduced between said surfaces as a result of said device being touched.

6. A device as claimed in any preceding claim, wherein a portion of said signal pass through said surfaces.

7. A device as claimed in any preceding claim, wherein said surfaces are substantially parallel to each other.

8. A device as claimed in any preceding claim, in which said light source is caused to move across said surfaces, said device further comprising means for coordinating the position of said signal with said output to determine the position of said touch.

9. A device as claimed in any preceding claim, wherein said signal source is a cathode ray tube and wherein said signals which are introduced between said surfaces are light signals from said cathode ray tube.

10. A device as claimed in claim 5, wherein said signal utilization means includes at least one light detecting diode.

11. A device as claimed in claim 5, wherein said signal utilization means includes optic fibers.

12. A touch sensitive device substantially as hereinbefore described with reference to the accompanying drawings.

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